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Observations of tidal energy and tidal fluxes through the Turkish Straits System

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From September 2008 through February 2009, The U.S. Naval Research Laboratory in collaboration with NATO Undersea Research Centre and the Turkish Navy Office of Navigation, Hydrography and Oceanography, used 8 Acoustic Doppler Current Profilers (ADCPs) in 4 pairs to measure currents and pressure at the entrances and exits to the Dardanelles and Bosphorus Straits inside the Turkish Strait System. The variability of currents in the system are dominantly at synoptic and lower frequencies and the mean two layer exchange of Aegean and Black Sea origin water has been the focus of much prior research. However, current fluctuations at tidal frequencies also play a role in the Straits, reaching 20% of the total variance in the mid-water column of the Southern Dardanelles. Measurement of tidal currents and pressures simultaneously allows the calculation of the energy fluxes of the barotropic tides. Preliminary estimates from select stations suggests that net tidal energy passes from the Aegean to the Dardanelles (1.2 MW K_1, 0.6 MW M_2), from the Dardanelles to the Sea of Marmara (0.3 MW K_1, 0.2 MW M_2), from the Sea of Marmara to the Bosphorus (0.005 MW K_1, 0.054 MW M_2), and from the Black Sea to the Bosphorus (0.006 MW K_1, 0.086 MW M_2). These results imply that the Turkish Strait System acts to dissipate and/or generate baroclinic tides from the supplied barotropic tidal energy and that this action in the Dardanelles is frequency selective, creating an effective barrier to barotropic diurnal energy transmission.

Although little barotropic tidal energy was found to pass from the Dardanelles to the Sea of Marmara, total tidal energy levels inside the strait itself were similar between the southern and northern sections. However, the distribution of tidal energy was very different between these two sections. For M_2 tides in the Dardanelles, modest levels of potential energy at the Aegean entrance appear to be almost entirely transformed into kinetic energy at the Sea of Marmara entrance. Thus, while tidal sea-surface-height fluctuations significantly decrease in the Dardanelles from north to south, tidal currents increase due to both this effect and to a narrowing of the passage. In all measured sections of the Turkish Strait System, estimates of tidal kinetic energy greatly exceeded tidal potential energy. For K_1 tides in the Dardanelles, 97% of the kinetic energy was in the form of vertically-uniform currents at the Aegean (southern) entrance but only 64% was in this form at the Sea of Marmara (northern) entrance. Much less (93% to 87%) of the M_2 kinetic energy was transformed in this way, suggesting the existence of a frequency selective action of baroclinic tide generation in the Dardanelles. As expected from the energy flux estimates, tidal energy was generally much lower in the Bosphorus than in the Dardanelles, and primarily at semidiurnal frequencies. Also, less of the tidal kinetic energy was carried by vertically-uniform currents in the Bosphorus for both K_1 (60% and 73%) and M_2 (74% and 64%) tides. Our analysis finds that the Turkish Strait System acts both as a barrier and a transformer of tidal fluctuations.